Name of Organization: SUNY-Binghamton

Type of Organization: College or University

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Project Title: Waste Minimization in the Instructional Laboratory

Project Category: Pollution Prevention and Reduction - BNS

Rank by Organization (if applicable): 0

Total Funding Requested ($): 140,384 **Project Duration:** 2 Years

Abstract:

Traditionally, colleges and universities have been insulated from the concerns and investigations surrounding the generation and disposal of chemical waste. However, it is being increasingly recognized that these locations do generate significant amounts of waste that require better monitoring with respect to both generation and disposal practices. While the research end of waste generation is an obvious target, instructional laboratories are nevertheless significant generators of waste. For example, roughly 25% of the waste generated by the chemistry department at SUNY-Binghamton is from the instructional laboratories (general chemistry and organic chemistry lab courses). Even with the implementation of microscale experiments, the chemistry instructional laboratories at SUNY-Binghamton generate over 200 gallons of hazardous waste each year - a value typical for medium-sized universities and colleges all across the country. Further, these experiments often still employ toxic halogenated solvents which can readily find their way into the watershed. To further reduce instructional laboratory waste new laboratory experiments are needed. Implementation of modern synthetic chemistry and methods that have been developed to address these same concerns at the industrial level provides the opportunity to not only reduce the waste generated in instructional laboratories, but also to increase public awareness of how chemistry can be made compatible with the environment.

Geographic Areas Affected by the Project

States:

- [x] Illinois
- [x] Indiana
- [x] Michigan
- [x] Minnesota
- [x] New York
- [x] Pennsylvania
- [x] Wisconsin
- [x] Ohio

Lakes:

- [ ] Superior
- [ ] Huron
- [ ] Michigan
- [ ] Erie
- [ ] Ontario
- [x] All Lakes

Geographic Initiatives:

- [ ] Greater Chicago
- [ ] NE Ohio
- [ ] NW Indiana
- [ ] SE Michigan
- [ ] Lake St. Clair

Primary Affected Area of Concern: Not Applicable

Other Affected Areas of Concern:

For Habitat Projects Only:

Primary Affected Biodiversity Investment Area: Not Applicable

Other Affected Biodiversity Investment Areas:

Problem Statement:

Traditionally, colleges and universities have been insulated from the concerns and investigations surrounding the generation and disposal of chemical waste. However, it is being increasingly recognized that these locations do generate significant amounts of waste that require better monitoring with respect to both generation and disposal practices. While the research end of waste generation is the obvious target, instructional laboratories are a particular problem since most existing experiments predate any significant concern with regards to environmental impact and waste management. While this is a problem that exists in all parts of the country, it is particularly important in the New England States and the Midwest (both of which heavily impact the Great Lakes watershed) due to the high number of state and private academic institutions in these areas. Wastes from these instructional laboratories find their way into the watershed through a variety of pathways including poor material management, inadequate recognition of water contamination, and use of older, highly toxic reagents and procedures. Perhaps the most over-looked source of water contamination is the aqueous layers from simple aqueous/organic extractions. Many, if not all, of the aqueous layers from these simple extractions are simply tossed down the drain. However, a typical aqueous extraction of an organic reaction with water can leave significant quantities of the organic solvent in the aqueous layer. This is particularly a problem when dealing with the halogenated solvents such as methylene chloride or chloroform. These solvents are not only toxic and flammable, but also, due to the fact that they are more dense than water, they tend to collect over time in lakes and slow moving streams. This results in even higher local concentrations of these toxic solvents and greater poisoning of the flora and fauna of lakes. Taking methylene chloride as an example, a typical extraction between water and methylene chloride leaves 0.005% methylene chloride in the aqueous layer. This means that for every liter of aqueous waste generated, roughly 50 mg of methylene chloride are present. From a typical laboratory experiment at least two liters of this aqueous waste would be generated by twenty students. Over the course of an entire semester at a university such as SUNY-Binghamton, this would result in over 15 grams of methylene chloride being flushed down the drain. Added up over the entire Great Lakes' basin and this number becomes staggeringly large. Clearly, these same issues have already been encountered and dealt with in the industrial setting, so a similar approach could and should be implemented in the academic instructional environment.

Proposed Work Outcome:

The first stage of this project is to develop a series of organic laboratory experiments that will reduce waste in the instructional laboratory setting, while not requiring expensive, exotic equipment and chemicals. Additionally, these new experiments must still teach the same key concepts and techniques that older procedures did, but without the hazardous waste. This goal can be accomplished in a number of ways, taking cues from what has proven to be successful in the industrial and research areas of chemistry. The first obvious method of waste reduction will be to recycle the solvents used in the reactions, extractions, and chromatography. Solvents make up the bulk of the waste generated, so their separation and collection by means of standard laboratory equipment such as rotary evaporators would be a significant start in

reducing waste from the instructional laboratory. The use of flammable and/or toxic solvents can be further reduced by employing reactions that can be run in water or in ionic liquids. In both of these cases, the reaction solvent is now a safe and environmentally benign material with greatly reduced concerns regarding handling and disposal. Even the disposal issue of aqueous extractions contaminated with toxic halogenated solvents can be eliminated by avoiding the use of these solvents. Non-toxic alternatives which are also less water soluble are known, and, in combination with solvent recycling efforts, can be accommodated even within the financial constraints of the typical laboratory course. Finally, the adverse impact of the waste stream can be further reduced by employing reactions which do not require potentially toxic metal reagents, but instead use catalysts and cleaner stoichiometric reagents (such as bleach for oxidations). Finally, waste can be even further reduced by generating "useful" products. This will involve either setting up instructional laboratory experiments that prepare compounds that are of use in the research laboratories of professor's within the department or designing sequences of experiments in which the product of one reaction can be transformed back into the starting material for that first reaction.

Once these experiments and chemicals have been identified, the second stage is to test that these items will function reproducibly and safely under typical instructional laboratory conditions. This will first involve select beginning graduate and advanced undergraduate students running these experiments to insure that they perform satisfactorily. The next phase will implement the successful protocols in the general instructional laboratories. By testing new experiments over a period of several semesters, a variety of experiments will be developed that will provide a sufficient basis for a solid, yet-varied, organic laboratory course.

The final stage will be the broad dissemination of the results of this proposal. Clearly the objective of a project such as this is not to simply correct the waste situation at a single university, but to develop a program that could operate satisfactorily at universities and colleges across the entire United States. This will involve the publication of the experiments developed through this study via traditional printed media as well as via Web-based media. This will insure the widest possible audience and give the greatest opportunity for the most significant impact from this study.

Project Milestones:	**Dates:**
Concept Discussion and development	11/1999
Testing of new experiments	09/2000
Laboratory implementation	01/2001
National presentation of results	09/2001
Evaluation and further implementation	09/2001
National presentation of results	03/2002
Preparation of published manual	08/2002
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☐ Project Addresses Environmental Justice

If So, Description of How:

☒ Project Addresses Education/Outreach

If So, Description of How:

There are two facets to the educational outreach component of this proposal. The first is simply the fact that this entire project focuses on revising the instructional laboratory courses at educational institutions so that they are more efficient and generate less waste. The second aspect is perhaps slightly less obvious. However, by introducing these changes in how organic chemistry is taught in the laboratory setting, the students are also exposed to the techniques that are/can be employed in private sector to make synthesis environmentally compatible. Issues such as the source and effect of common organic wastes and ways to treat and avoid these same problems will be directly integrated into this new instructional approach. This knowledge will thus be transferred to students with a broad range of interests and career goals, ranging from chemistry and biology to medicine and engineering, since many majors require chemistry up through the organic laboratory for graduation. This in turn will create a public that is better informed and equipped to deal with the growing list of environmental and technical issues facing society today.

Project Budget:

	Federal Share Requested ($)	Applicant's Share ($)
Personnel:	55,825	9,135
Fringe:	5,227	2,664
Travel:	2,000	0
Equipment:	0	0
Supplies:	30,000	20,000
Contracts:	0	0
Construction:	0	0
Other:	600	10,200
Total Direct Costs:	93,652	41,999
Indirect Costs:	46,732	5,888
Total:	140,384	47,887
Projected Income:	0	0

Funding by Other Organizations (Names, Amounts, Description of Commitments):

Description of Collaboration/Community Based Support:

Active collaboration and support for this effort will initially be primarily at the university level. SUNY-Binghamton currently has the Center for Research on Environmental Systems, which is dedicated to the study of a variety of environmental issues and concerns. Ideas and possible ways in which similar plans could be used to reduce waste from other science instructional laboratories will be discussed by this center as results from the proposed study become available. Teaching innovations are also well supported at SUNY-Binghamton by the presence of the Center for Learning and Teaching. This center is particularly adept at disseminating new teaching methods and practices and will serve a similar function at spreading the results of the proposed study. On a regional level, the Great Lakes Consortium provides an avenue for the rapid dissemination of ideas and results within the 13 universities in New York and 8 more in Canada. Finally, the introduction of safe and environmentally conscious educational practices is a key goal of the Partnership for Environmental Technology Education. This national organization has as its stated goal the facilitation of industrial and governmental partnerships to address the education and environmental training needs of the nation. Among their ways of achieving this goal is the development of new laboratory courses that focus on environmental concerns - a goal shared by the research efforts outlined in this proposal.